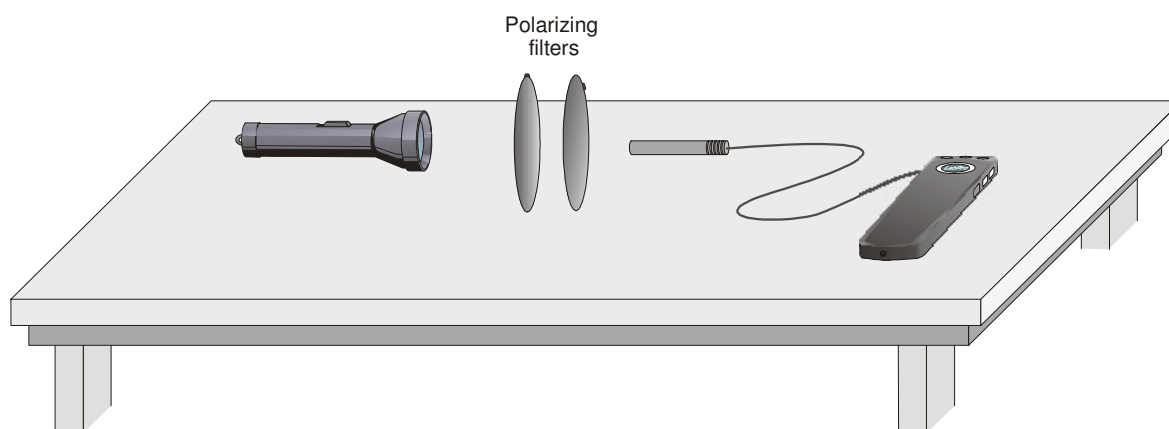


Polarization of Light

Perhaps you have seen a display of polarized sunglasses in a store. You can quickly test to see if the glasses are really polarized by looking through the lenses of two glasses and rotating one pair by 90° . If both pair of glasses are polarized, the lenses will appear to go black. Why is that?

To explain the darkened lenses, we need to think of the light as an electromagnetic wave. An electromagnetic wave has varying electric and magnetic fields perpendicular to the direction the wave is traveling. This experiment focuses only on the electric field variation, represented by a vector. Light emitted from a typical source such as a flashlight is randomly polarized, meaning that the electric vector points in varying directions.

An ideal polarizing filter will remove all but electric fields that are parallel to the axis of the filter. The light remaining is then said to be *polarized*. A second filter can be used to detect the polarization; in this case, the second filter is called an *analyzer*. The transmission through the second filter depends on the angle between its axis and the axis of the first filter. In this experiment you will study the relationship between the light intensity transmitted through two polarizing filters and the angle between the filter axes.



OBJECTIVES

- Observe the change in light intensity of light passing through crossed polarizing filters.
- Measure the transmission of light through two polarizing filters as a function of the angle between their axes and compare it to Malus's Law.

MATERIALS







Power Macintosh or Windows PC
Light Sensor
LabPro or Universal Lab Interface
Logger *Pro*

light source
polarizing filters (2) with marked axes
protractor

PRELIMINARY QUESTIONS

1. Place one polarizing filter on top of a second so you have to look through both of them. Rotate the top filter until the axis marks are at right angles to one another. What do you notice?
2. Rotate a filter so the axes are now parallel. Look through the stack and rotate the top filter about your viewing axis by 180°. Make a qualitative graph of the transmitted light intensity you observed as a function of the angle.

PROCEDURES

1. Place the light source, polarizing filters, and Light Sensor so light passes through the filters and then into the sensor. You will rotate only one filter to change the transmission; the other filter, the light source, and the sensor must not move. Turn on the light source.
2. Connect the Light Sensor to Channel 1 of the LabPro or the Universal Lab Interface. If your sensor has a range switch, set it to the 600-lux range.
3. Open the Experiment 1 folder from *Physics with Computers*. Then open the experiment file that matches your type of Light Sensor. Light intensity is plotted vs. analyzer angle. Data will be collected in Event with Entry mode, meaning that the light intensity will only be measured when the  button is clicked. You will then type the analyzer angle in degrees and press ENTER to complete the data point.
4. Rotate the analyzer until the Light Sensor reading is maximized. The Light Sensor reading is shown in the status bar at the bottom of the Logger Pro window. If the reading is larger than 600 lux, reduce the intensity of the light source and rotate the analyzer again for maximum sensor reading. This is your zero angle. The axis marks on the two filters should be parallel.
5. Set the filters so their axes are at right angles. Very little light should get through the pair of filters. Define the light level as zero by clicking . The intensity reading should now be near zero.
6. Return the analyzer to the parallel position. Click  to begin data collection. Click  to take the first point and enter 0 for the angle. Press ENTER to complete the entry.
7. Rotate the analyzer by 15°, click , and enter 15 for the angle. Repeat this process, entering 30 for the next angle, and so forth, until you have rotated the analyzer through one revolution, or 360°. Click  to end data collection.


ANALYSIS

1. Describe your graph of light intensity vs. angle, giving important patterns and points.
2. In the 1800's Malus proposed

$$I = I_0 \cos^2(\theta)$$

to predict the light transmission through two polarizing filters, where I_0 is the intensity when the angle θ between the polarizer axes is zero.

You can use the Manual Fit feature of Logger Pro to superimpose this relationship on your experimental data. Select Manual Fit from the Analyze menu. In the Equation field of the resulting dialog box enter $A*(\cos(x))^2$. In this equation x stands for the angle θ .

3. To compare your data to the model, you must adjust the value of A so that A matches the maximum intensity of your data. To do this, either enter a number in the A field or click  to the right of the A parameter field. Adjust A as needed to achieve a good fit to your experimental data.
4. Click OK to plot your data and the Malus's law model on the graph at the same time.
5. Compare the data to the model. Are your data consistent with Malus's Law?

EXTENSIONS

1. Polarized sunglasses selectively remove glare caused by light reflected by horizontal surfaces, *e.g.*, the hood of a car or a wet highway. For polarized sunglasses to be effective, the glare must be polarized. Devise an experiment to measure how strongly polarized the glare is compared to sunlight or to a flashlight. You will need a smooth horizontal surface to create glare, a bright light source, a polarizing filter, and your Light Sensor and interface. How is the axis of the polarizer oriented when the glare is minimized?
2. Set your two filters so that the polarizing axes are at 90° . Add a third polarizing filter between the first two and collect data of the transmitted intensity as a function of the angle of the middle filter. Explain the shape of the graph with a vector model.